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EFFECT OF CROP AND MACHINE PARAMETERS ON CUTTING ENERGY FOR HARVESTING OF BENGAL GRAM CROP

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ABSTRACT

The study was carried out to investigate the effect of stem diameter, moisture content of the crop, stroke length and cutter bar speed on cutting energy for development of bengal gram harvester. At present, bengal gram is harvested manually by sickle. Experiments were carried out at two levels of stroke length of the cutter bar (50 mm and 76.2 mm) , four levels of cutter bar speeds (0.25, 0.50, 0.75 and 1.0 ms^{-1}), three levels of stem diameter (3 to 4.5 mm, 4.51 to 6 mm and greater than 6 mm) and three ranges of moisture content 20.2 to 20.45 (at 5 days before harvesting stage), 18.1 to 18.6 (at harvesting stage), and 14.8 to15.1 per cent (at 5 days after harvesting stage). The cutting energy required for harvesting of Bengal gram was calculated for all the treatments. Increase in cutter bar speed from 0.25 m $s^{-1}$to 1.0 m s^{-1} resulted in 4.54, 5.97 and 10.20 per cent reduction in cutting energy required respectively for 3 to 4.5, 4.5 to 6 and more than 6 mm diameter of stem.

KEYWORDS: Bengal Gram, Cutting Force, Cutting Energy, Stroke Length & Cutter Bar Speed

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Original Article

1. INTRODUCTION

Bengal gram is also called as chickpea or gram (*Cicer aritinum. L*) in South Asia and Garbanzo bean in western countries. Bengal gram belongs to Leguminoseae family. It is traditionally cultivated in many parts of the world in a wide range of agro climatic environments. It is cultivated mostly as a rainfed crop during post-rainy (winter) season in subtropical south Asia and in the parts of Africa and Australia. Bengal gram is a small, branched herbaceous plant. There are two types of bengal gram viz., desi (dark colour seed coat and smaller seeds) and kabuli (white or cream colour seed coat and comparatively larger seeds). Bengal gram helps in fixing nitrogen from atmosphere which improves organic matter content in the soil. A bengal gram crop could fix up to 141 kg N ha^{-1}, which economizes nitrogen application for succeeding cereals to the tune of 56 to 58 kg N ha^{-1} The bengal gram contains 21 per cent protein, 61.5 per cent carbohydrate, 4.5 per cent fat and is also rich in calcium, iron and niacin **(Ahlawat *et al.*1981).**

More than a dozen pulse crops are grown in different parts of India. Among them, bengal gram is a major food legume and important pulse crop. This accounts for about 46 per cent of the total production of pulses and 65.39 per cent of the total world production of bengal gram. Hence, it is known as king of pulse crops (Anon., 2018). In Tamil Nadu, bengal gram is harvested manually using sickle, which is tedious and drudgery operation. Harvesting of bengal gram at optimum maturity is essential for ensuring quality and productivity of crops. The

harvester basically designed for wheat crop are not suitable for crop like bengal gram, soybean and gram, because the crop height is not adequate and the branches with pods are close to ground due to semi-spreading growth habit. Harvesting operation consists of cutting and conveying of crops. The quality of harvesting and also the energy required for cutting are influenced by linear speed of the cutter bar. Operational speed of the cutter bar is the most significant features of reciprocating cutter bar (O'dogherty and Gale, 1991). The other factors that affect the cutting force and energy were stem diameter and moisture content of the crop (Ranganna, 1995 ; Prakash, 2003 and Tawadare, 2007).

2. MATERIALS AND METHODS

The pertinent crop parameters (moisture content, stem diameter) and machine parameters (linear speed of the cutter bar and stroke length of cutter bar) were identified as influencing parameters for the harvesting of crop.

2.1 Crop Parameter

2.1.1 Moisture Content of the Crop

The harvesting of bengal gram crop is normally observed between 90 to 105 days of duration. The actual harvesting is done as fully green leaves turn to reddish brown and start shedding. For determining the cutting force and energy, moisture content (wet basis) of the crop at three stages *viz.,* five days before harvesting stage 20.2 to 20.45 per cent, at the time of harvesting stage 18.1 to 18.6 per cent and five days after harvesting stage 14.8 to 15.1 per cent was measured using hot air oven. The moisture content was calculated by the following expression.

$$\text{Moisture content of the crop (w.b) , per cent} = \frac{W_m - W_d}{W_m} \quad (1)$$

Where,

W_m is the weight of stem before drying, g

W_d is the weight of stem after drying, g

2.1.2 Stem Diameter

The stem diameter is defined as the diameter of plant measured (height at which actual harvesting is done) above the ground level. At optimum harvesting stage ten samples of bengal gram crop were selected randomly in the field and diameter of the stalk was measured using vernier caliper. From the measured values, the diameter for the predominant variety of Bengal gram crop varied from 3 to 8 mm. Hence the stem diameters of 3 to 4.5 mm, 4.5 to 6.00 mm and more than 6 mm were selected for the study.

2.2 Machine Parameters

2.2.1 Linear Speed of Cutter Bar

The linear speed of cutter bar was calculated using the following equation (Celik, 2006).

$$V_k = \frac{Sn}{30} \quad (2)$$

Where,

V_k = knife speed, m s^{-1}

S = length of stroke, m

n = crank speed, rpm

Four cutter bar speeds were selected for the study based on the cutting speed selected by earlier researchers are 0.25, 0.5, 0.75 and 1m s^{-1}

2.2.2 Stroke Length

Cutting efficiency and uniformity of cut are influenced by the stroke length of cutter bar. (Kathirvel *et al.,* 2009,2011). The cutter bar of 76.2 mm stroke length is in used to cut grasses, cereals and commercial crops of thin stalk (Das, 1998). The Bengal gram stems are thinner diameter. The commercially available harvesting units have cutting blade of width 76.2 and 50 mm was selected for the study.

2.3 Evaluation Parameters

2.3.1 Cutting Energy

The cutting energy was calculated by using equation 3

$$E_C = F_C \times D \quad (3)$$

Where,

E_C = cutting energy, J

F_C = cutting force, N

D = diameter, m

$$F_C = PF_C \times 9.87 \quad (4)$$

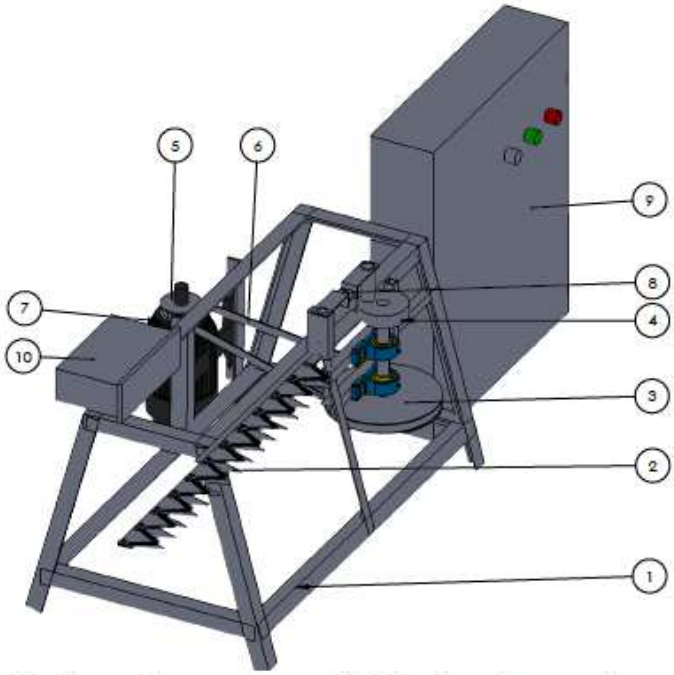
F_c = cutting force of the crop, N

The cutting force of the crop was measured by using double knife cutter bar test rig.

PF_c = peak cutting force of the crop, kg

2.3.2 Double Knife Section Cutter Bar Test Rig

A test rig was developed to measure cutting force using a reciprocating double knife section cutter bar. It consists of a motor, cutter bar assembly, power transmission system, variable speed drive, load cell and load indicator (Figure 1). The S-type load cell was used to measure the cutting force in kilogram. The load cell was arranged on the connecting rod between the cutter bar and crank. The bengal gram crop was fed between the two cutter bar blades. The stem was cut into two pieces. The cutting force exerted by cutter bar was sensed by the strain gauges in the load cell and the values were indicated in kg in the digital load indicator. Experiments were carried out at two levels of stroke length of the cutter bar 50 mm and 76.2 mm, four levels of cutter bar speeds 0.25, 0.50, 0.75 and 1.0 ms^{-1}, three levels of stem diameter 3 to 4.5 mm, 4.51 to 6 mm and greater than 6 mm and three ranges of moisture content 20.2 to 20.45 (at 5 days before harvesting stage), 18.1 to 18.6 (at harvesting stage), and 14.8 to15.1 per cent (at 5 days after harvesting stage). The cutting energy required for harvesting of bengal gram was calculated for all the treatments.



S.No.	Components	S.No.	Components
1	Main frame	6	Belt drive
2	Double knife cutter bar	7	Electric motor
3	Driven pulley	8	Load cell
4	Slider crank mechanism	9	Variable speed drive
5	Drive pulley	10	Load indicator

Figure 1: Double Knife Section Cutter Bar Test Rig.

3. RESULTS AND DISCUSSIONS

The effect of crop and machine parameters viz., diameter of the stem, moisture content of the crop at selected level of harvesting, cutter bar speed and stroke length on cutting energy required for harvesting Bengal gram crops were analyzed and the results were discussed below.

3.1 Effect of Cutter Bar Speed on Cutting Energy at Selected Stem Diameter

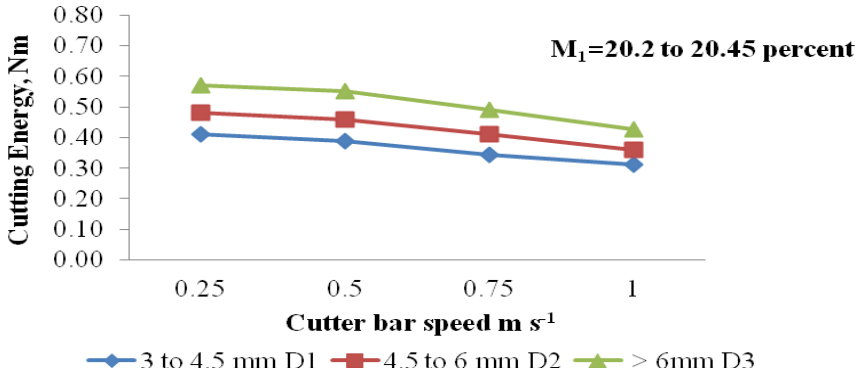


Figure 2: Effect of Cutter Bar Speed on Cutting Energy.

From the Figure 2, it is noticed that increase in cutter bar speed from 0.25 to 1.0 m s^{-1} resulted in gradual

reduction of energy required for harvesting 3 to 4.5, 4.5 to 6 and more than 6 mm diameter of stem. The minimum energy of 0.38 Nm was registered at 1.0 m s^{-1} cutter bar speed for cutting 3 to 4.5 mm diameter of stem. The maximum energy of 0.67 Nm was observed at 0.25 ms^{-1}cutter bar speed for cutting more than 6 mm diameter of stem.

3.2 Effect of Stem Diameter on Cutting Energy at Selected Moisture Content

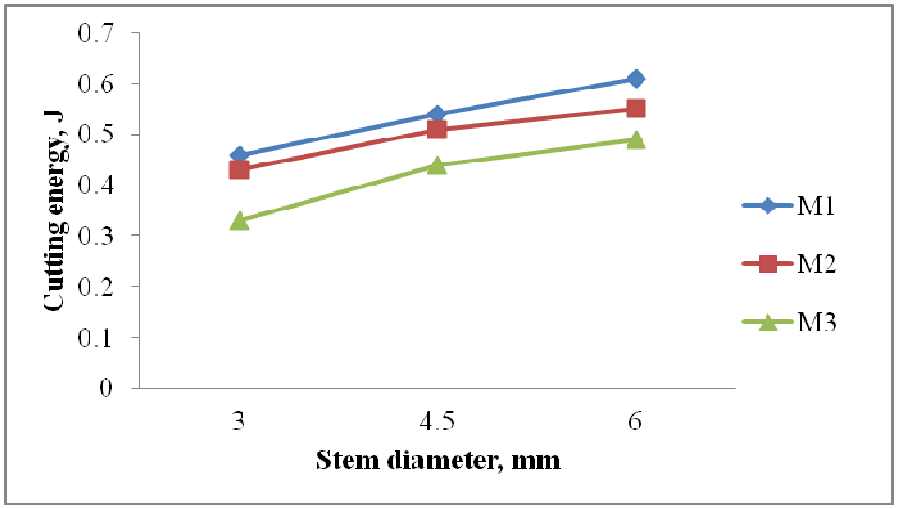


Figure 3: Effect of Stem Diameter on Cutting Energy.

From the Figure 3, it is inferred that increase in stem diameter of bengal gram crop from 3 to 6 mm resulted in increasing of energy required for harvesting of crop at selected moisture contents. The minimum and maximum cutting energy of 0.38 Nm was registered at 3 to 4.5 mm diameter of cutting 14.1 to 15% moisture content and 0.67 Nm at more than 6 mm for cutting of 20.2 to 20.45% moisture content of the crop.

3.3 Effect of Moisture Content on Cutting Energy at selected Cutter Bar Speed

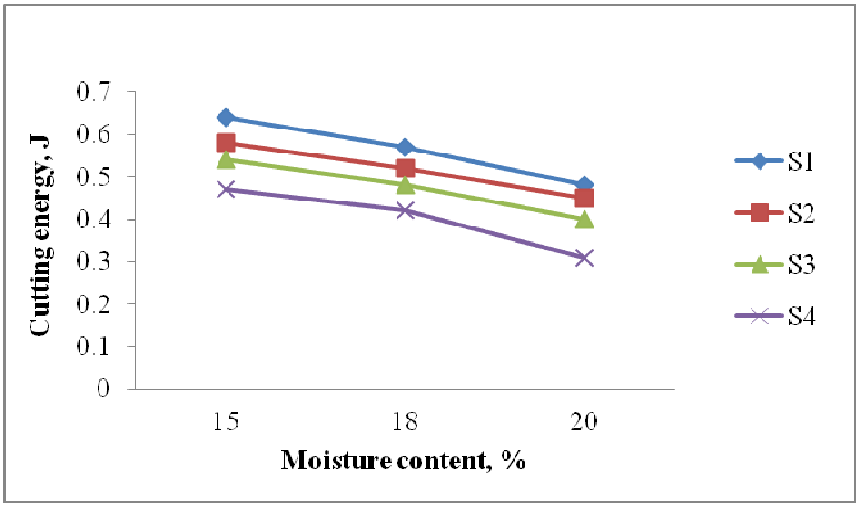


Figure 4: Effect of Moisture Content on Cutting Energy.

From the Figure 4 , it is noticed that decrease in moisture content of bengal gram crop from 20 to 15 % mm resulted in increase of energy required for harvesting at 0.25,0.5,0.75 and 1 m s^{-1}contents. The maximum energy of 0.67 Nm was observed at 15 percent moisture content for cutting 0.25 ms^{-1}cutter bar speed. The minimum energy of 0.38 Nm was registered at 20 percent moisture content for cutting 1.0 m s^{-1} cutter bar speed.

3.4 Effect of Stroke Length on Cutting Energy at Stroke Length

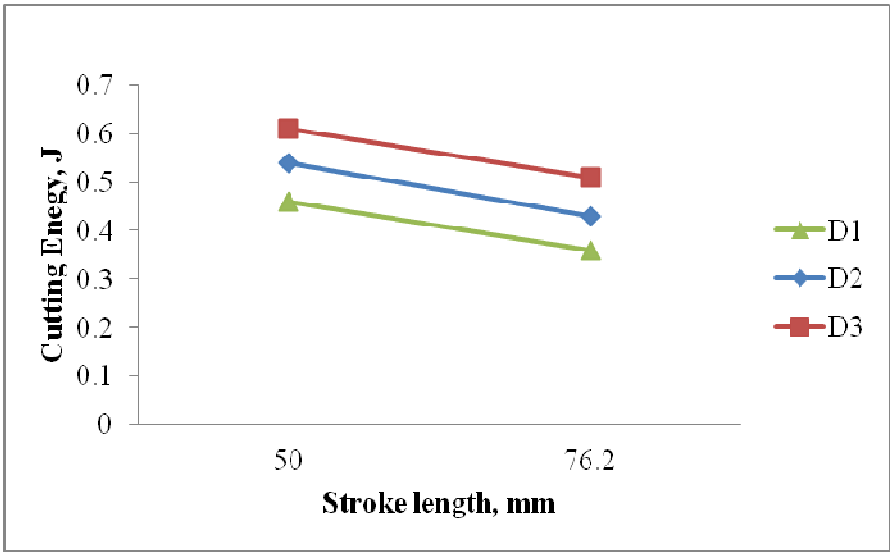


Figure 5: Effect of Stroke Length on Cutting Energy.

It is inferred from Figure 5 that the cutting energy required for cutting Bengal gram was minimum for 76.2 mm stroke length at selected levels of cutter bar speed, diameter and moisture content of crop. The overall reduction in energy required for cutting varied from 18 to 21.1 per cent with 76.2 mm stroke length of cutter bar when compared to 50 mm stroke length

4. CONCLUSIONS

The power requirement for designing of harvesters was calculated using measured values. The stoke length, cutter bar speed and moisture content showed a negative correlation with cutting energy. It was observed that stem diameter shows a positive correlation with cutting force. It was concluded that the double knife cutter bar required minimum cutting energy of 0.67 Nm for cut the bengal gram crop.

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